Using Drones to Sample Insects in Soybeans
Project 25-2021

Final Report

Project PIs

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Background and Objectives: Scouting large soybean fields is a time-consuming, tiring task. When beans are drilled or when beans get tall and lodge, walking through a soybean field can become almost impossible. As a result, large soybean fields seldom get sampled properly, with many decisions made based on conditions found on the portion of the field near the access point. Unfortunately, since many insects have a clumped distribution, the density near the access point may not accurately reflect the pest pressure in the entire field, meaning that insecticide applications may not be optimized.

Unmanned aerial vehicles (UAV), also called drones, are becoming increasingly affordable and easy to use. A variety of attachments can enable drones to do a wide variety of tasks, and applications are being developed in numerous areas of agricultural production. Mississippi State University has emerged as one of the leaders in the use of drones in agriculture, and this project will build on this knowledge base. The use of drones in insect sampling has been studied in a few situations but is still in its infancy. Most drone sampling research to date has used imagery as the means of sampling, often measuring plant stress rather than counting insects directly. However, to make this monitoring method useful in regions like Mississippi with multiple potential pests causing similar injury, an insect recognition method is needed. For example, management strategies differ for soybean looper, green cloverworm and bean leaf beetle even though they all cause similar plant stress. Therefore, defoliation imagery is not sufficient for making an appropriate management recommendation. While insect identification could theoretically be done with image recognition software, the technology to effectively identify insects in a complex environment like a soybean field is still not available. As an alternative that could be adopted more rapidly, we are exploring the possibility of attaching a light sweep net to a drone to facilitate sampling. During 2019 and 2020 we developed a system where the drone operator can send the drone to the field, collect a sample, return the drone to the field edge where the sweep net is detached, and another sweep net is attached to the drone. If two people are available, the drone operator can go collect another sample while the second person counts the insects in the sweep net. If the drone operator is alone, he can count the insects in the net before sending the drone out for a second sample. Drone sampling enables rapid sampling throughout a large field at any stage of growth, may be as consistent as human sampling, and avoids the uncertainty and complex computing needs of automated insect recognition. During 2019 we developed and tested the sweep net prototype. This report will provide information collected during 2020 and 2021 on the three objectives listed below.

Objectives:

1. Develop a drone-powered effective sampling method for insects in soybeans. This will improve sampling efficiency and the quality of insect management decisions, especially in fields where walking is difficult.

2. Correlate the drone sampling method to the current manual sweep net and drop cloth sampling methods. This is necessary so that existing action thresholds can be adapted for data collected using the

drone sampling method.

3. Conduct an economic comparison of the drone, manual sweep net and drop cloth sampling methods based on the time required to collect equivalent quality of samples. This will allow growers and consultants to decide where and when the drone sampling method improves sampling efficiency.

Report of Progress/Activity:

Objective 1:

A second drone was purchased which was the same model as the one we already owned. Adaptations were made to the drone to enable it to sample with a sweep net. Drone flights were conducted using software so that drone speed, height and sampling distance could be precisely maintained. Minor changes to the proposed speeds and sampling distances to be tested were made based on preliminary observations. After conducting numerous flights using the drone programming software, it became obvious that this method was not practically feasible for our application because it was time consuming to program, and it was not sensitive enough to altitude (one time the drone would be too high and the net would be above the soybeans, and the next time it would be too low and crash into the soybeans without making any change in the program). However, an experienced pilot with manual control of the drone is able to consistently keep the sweep net in the canopy as desired without crashing the drone. Therefore, we adopted manual drone control as the standardized method for objective 2.

Objective 2:

Sweep net, drop cloth, and drone samples of 25 m and 50 m in length were collected from 87 soybean fields at various growth stages containing a wide range of soybean insect densities during 2020 and 2021. All insect samples were placed in plastic bags and frozen for later enumeration. The data were entered into the computer for statistical analysis.

Counts of 12 insect species were recorded. Because they commonly occur together and most cause similar damage, for this analysis, five species of Lepidoptera were combined into the Lepidopteran complex for analysis. Similarly, 4 species of stink bugs were combined and analyzed as the stink bug complex. Bean leaf beetle was too rare to evaluate the sampling methods, so was excluded from all analyses. Therefore the 4 sampling methods were compared for threecornered alfalfa hopper, kudzu bug, the lepidopteran complex and the stink bug complex. Based on the overall correlations for these insects (Table 1) we conclude that:

(1) drone sweeping for 25-m is as good or better than drone sweeping for 50-m. The number of insects caught in the 50-m sample was much less than two times the 25-m sample, and the 25-m r-values were similar or better than the 50-m r-values.
(2) The relationship between drone and sweep net samples was comparable to drop cloth with sweep net samples. R-values show how much of the variability is explained by the correlation of one sampling method with the other. The drone 25 to sweep net r-values are comparable to the drop cloth to sweep net r-values for all species. A more important relationship for crop consultants and growers is whether the different sampling methods lead to the same management decision. After creating tentative thresholds for the drones and drop cloths (when needed) based on correlations with the sweep net, we determined that the likelihood of making a bad recommendation (spraying when not needed or not spraying when needed) was similar for all comparisons of drones, sweep nets and drop cloths (Only 1 method>ET column in Table 2). Even for lepidopteran larvae and stink bugs where both drop cloth and sweep net thresholds are published, the agreement between these 2 manual sampling methods was similar to or slightly better than the agreement between a drone sample and one of the manual samples. Based on these statistical comparisons, it appears that the drone sampling

method provides a similar quality of data as the current manual methods.

(3) The actual number of insects caught per sample with a drone were much lower than with a manual 25-sweep sample, but as long as appropriate thresholds are used, this sampling method can be used.

(4) Covariate information was collected, and final analysis of the impact of these on any of the sampling methods is not complete. However, tentative conclusions from this covariate analysis suggests that while several covariates are statistically significant for various sampling method-insect combinations, none appear to be consistently important to sampling accuracy.

Objective 3:

Time needed to collect samples was recorded for all sampling methods during both years. The time required to collect four samples using a manual sweep net or drop cloth was slightly faster than using the drone (Table 3). However, all the sampling occurred within 30 m of a field edge, and most samples were collected under conditions when walking in the field was easy. If tested by sampling further into large fields or under conditions where walking was difficult, the time required for the manual methods would increase, but wouldn't change much for the drone methods. The time required for sampling 50-m and 25-m with a drone were equal. This is because very little of the 10 minutes was used to directly collect insects. Most of the time was getting the drone to and from the sampling location and changing the nets between each of the four samples. What has not been determined yet is the number of samples required to make a management decision with equivalent precision using the various methods. This analysis will be conducted shortly and will be used to provide an estimate of the time required by each method to make a threshold determination of equivalent precision. An additional component of economic viability is the initial cost of each sampling method. While the cost of a sweep net and drop cloth are negligible, each drone used to collect the data in this trial cost about $4000. Furthermore, the drone used in this research is now obsolete, and replacement drones of the size needed to handle a sweep net cost >$10,000 due to the optical features now included (but that are not needed for sampling insects with a sweep net). Therefore, there needs to be substantial time savings or management decision improvements to justify this substantial capital expense. While our economic analysis is not yet complete, it is likely that drone sampling can only be justified if the drone is already purchased or is being purchased for an additional purpose.

Impacts and Benefits to Mississippi Soybean Producers

Approximately 90% of soybean acres are currently scouted for insects on a routine basis. If drone sampling proves to be a cost-effective method of sampling insects in soybean, we expect that most consultants would adopt this sampling method within 5-8 years under at least some conditions (when soybeans are hard to walk through). This will impact growers and consultants by reducing the cost (time) for scouting and/or improving the quality of the scouting, which will impact growers by improving their insecticide management.

End Products–Completed or Forthcoming

The following presentations were given:

Merkl, M, A. Catchot, L. Wasson and F. Musser. (2022) Utilizing unmanned aerial systems to sample insects in soybean. Virtual presentation at Southeastern Branch of the Entomol. Society of America annual meeting, San Juan, PR, Mar 28, 2022.

Merkl, M, A. Catchot, L. Wasson and F. Musser. (2022) Utilizing unmanned aerial systems to sample insects in soybean. BCH-EPP Department Graduate Student Seminar, April 1, 2022.

Informal presentations (mainly video clips) have also been presented at:

Southern Crop Pest Management Seminar, Oct. 13, 2021, Point Clear, AL.

S1080 Regional Soybean Pest Management Meeting, Feb. 16, 2022, Virtual

Forthcoming outputs from this research:

MS thesis by M. E. Merkl, Aug 2022.

Refereed journal article, Sept. 2022.

Graphics/Tables

Table 1. Correlations (r-values) and slopes of alternative sampling methods with sweep net samples in soybean during 2020-2021.

	Mean insects	Drone 25		Drone 50		Drop Cloth	
Insect Pest	/25 swp.	Slope	r	Slope	r	Slope	r
Three Cornered Alfalfa Hopper	15.53	0.17	0.67	0.23	0.68	0.19	0.53
Kudzu Bug	5.12	0.32	0.73	0.46	0.78	0.03	0.89
Lepidopteran Complex	6.60	0.18	0.70	0.13	0.37	0.38	0.81
Stink Bug Complex	4.26	0.24	0.56	0.30	0.57	0.27	0.61

Table 2. Tentative economic thresholds (ET) and decision agreement of sampling methods. N=87.

Method 1		**Method 2**				
Method	**ET**	**Method**	**ET**	**Both>ET**	**Only 1 Method > ET**	**Neither>ET**
Threecornered Alfalfa Hopper						
Drop	20	Sweep	100*	0.0%	1.1%	98.9%
Drop	29	Drone 25	18	0.0%	1.1%	98.9%
Drop	20	Drone 50	24	0.0%	2.2%	97.7%
Sweep	100*	Drone 25	18	0.0%	0.0%	100.0%
Sweep	100*	Drone 50	24	0.0%	1.1%	98.9%
Kudzu Bug						
Drop	26.1	Sweep	25*	10.3%	2.2%	87.4%
Drop	26.1	Drone 25	8.2	10.3%	1.1%	88.5%
Drop	26.1	Drone 50	12.2	9.2%	2.3%	88.5%
Sweep	25*	Drone 25	8.2	9.2%	3.4%	87.4%
Sweep	25*	Drone 50	12.2	8.0%	4.5%	87.4%
Lepidopteran Larvae						
Drop	20*	Sweep	38*	0.0%	3.4%	96.6%
Drop	20*	Drone 25	8.2	0.0%	6.8%	93.1%
Drop	20*	Drone 50	7.6	0.0%	10.3%	89.7%
Sweep	38*	Drone 25	8.2	2.3%	3.4%	94.3%
Sweep	38*	Drone 50	7.6	0.0%	11.5%	88.5%
Stink Bugs						
Drop	5.0*	Sweep	9.0*	6.9%	14.9%	78.2%
Drop	5.0*	Drone 25	2.3	6.9%	19.5%	73.6%
Drop	5.0*	Drone 50	3.0	9.5%	14.3%	76.2%
Sweep	9.0*	Drone 25	2.3	12.6%	16.0%	71.3%
Sweep	9.0*	Drone 50	3.0	14.3%	11.9%	73.8%

* Economic threshold published by MSU Extension. Kudzu bug published threshold is for nymphs only, but nymphs and adults were not recorded separately in this research.

Table 3. Time required to collect 4 insect samples from a field. N=73.

Method	**Time (minutes ± SEM)***
Drop Cloth (4 drops)	9.02 ± 0.31 A
Sweep Net (4 sets of 25 sweeps)	9.33 ± 0.24 A
Drone 50 M (Four 50-m samples)	10.00 ± 0.31 B
Drone 25 M (Four 25-m samples)	10.15 ± 0.28 B

* Times followed by the same letter are not significantly different (Fishers Protected LSD test at α=0.05)